APRIL 7.

The President, Dr. LEIDY, in the chair.

Twenty persons present.

The Primary Conditions of Fossilization.—Mr. CHARLES MORRIS made a communication in answer to the query: "Why are there no fossil forms found in the strata preceding the Cambrian?" In mineral conditions there is little difference between the two sets of strata. Yet the Cambrian contain numerous fossils, while the preceding strata are barren in this respect. This Cambrian life, however, does not come in the succession we might naturally expect, and it may be desirable to consider the succession which actually occurs.

Of Protozoa there is not a trace, if we reject the doubtful Eozoön. Yet vast numbers of Protozoa must have existed, and if there were any calcareous- or siliceous-shelled forms, as at present, they must have left some indication in the rocks. The Metazoa do not begin with the lowest forms, but the different orders make their appearance in very odd conjunction. Thus, at the very beginning, we have a great variety of tribolites, in conjunction with a much smaller variety of annelides and mollusks, while there are very scanty traces of sponges, echinoderms and the lower crustaceans. The most advanced form of these animals, the trilobite, greatly outnumbers all its contemporaries.

At a considerably later date two widely separated forms come together into existence. The low order of Hydrozoa makes its first appearance as the Graptolite, and at a closely related date appear Cephalopods, the highest order of Mollusks. The Silurian era opens with an abundance of Graptolites and a considerable increase of Cephalopods. It is much later ere any clear trace of Vertebrates appears, and this in what is certainly not their lowest form.

The appearance of land animals presents a somewhat similar phenomenon. No land Vertebrates appear below the Carboniferous rocks, yet it is now known that insects existed well down in the Silurian, proving that the conditions necessary for land life had very long prevailed ere Vertebrates left the sea for the land.

It is impossible to believe that these fossils represent truly either the beginning or the actual succession of life upon the earth. Such an idea would be utterly inconsistent with the development theory, and even under the creation hypothesis it is incredible that life could have begun with such a confused mixture of high and low. No one, for instance, can accept what the rocks seem to teach, that advanced forms of Mollusks and Crustaceans came into existence before the Cœlenterata. It may be taken for

granted that we have but fragments of the primeval life, and these fragments associated in a manner that cannot indicate the actual life conditions.

These earliest animals are mainly burrowing, crawling, or stationary forms. There is very little indication of the abundance of swimming life which now crowds the ocean and must have then done so. We find only minute swimmers, such as Pteropods and Phyllopods, while if the Trilobites were able to swim it must have been but a sluggish movement. There is no indication of the existence of rapid and powerful swimmers.

Yet there are several reasons for believing that swimming animals existed in abundance. The rapid swimmer has an advantage in food-getting and in escape from danger over the slow-moving surface animals. Natural selection, therefore, must have tended to produce swimming forms.

The facts of embryology yield evidence to the same effect. Nearly or quite all ocean animals begin life as swimmers. The stationary forms become fixed only after their larval period is passed. This fact indicates that at some early period the ancestors of our present fixed forms were free swimmers.

But a stronger proof of this is found in the condition of the animals whose fossil forms we possess. They are all covered with protective armor. It is, indeed, to the preservation of this armor that we owe our knowledge of their existence. We find no weapons of offense. Everything is defensive. Even the trilobite, which had nothing to fear from the other known forms, was clothed in a strong coat of mail, and had acquired the habit of rolling himself into an impenetrable ball. There can be no question that he had foes, stronger than himself, against whom he found defense only in his chitinous armor. Yet of these predatory foes we know nothing.

All other preserved forms tell the same story. We would know nothing of them but for their hard parts, and these hard parts are all protective. The soft-bodied annelid saved itself by burrowing in the mud. The mollusk clothed itself in a firm limy covering. Of the remaining forms each wore some kind of defensive armor. Many of them doubtless needed defense against the trilobites, but the foes of the trilobite are missing.

If we ascend higher in the rocks, the same tale is told. The Hydrozoa, which had probably swum the earlier seas in forms allied to our soft-bodied Medusæ, become stationary and protected as Graptolites. And simultaneously the powerful Cephalopods make their appearance as surface forms, clothed in a heavy and cumbrous defensive armor. If they formerly had mastery of the seas, as we may conjecture, they had been driven from it by some more powerful and rapid foe.

In fact all the preserved forms may be looked upon as to some extent degenerated types of life. They very probably represent

earlier free-moving forms, which have been driven to wear heavy armor for protection from stronger foes, and have been forced by the weight and the character of this armor to take up a life on the ocean bottom, either as stationary, crawling, or sluggishly swimming forms.

Where are the foes who have forced these forms of life into degenerated conditions? They are indicated in the rocks by no hard parts, either offensive or defensive. They probably needed no protective armor, they had no internal hard skeletons, and the only trace of early offensive weapons are found in the dubious Conodonts, of the lower Silurian strata. Not until undoubted fish teeth appear do we find unquestionable weapons of offense. And there is no indication of active predatory swimmers until we find the earliest fish remains. We may conceive that fishes had so increased as to sweep the seas of any overabundance of food forms, and had begun to actively prey upon each other. Then they developed the protective armor to which they had previously driven their prey. And this armor increased in thickness and strength until the remarkable bony plates of the Devonian fishes were produced. But in all probability several successive types of life obtained mastership of the ocean, each superior form driving all earlier forms to seek protection. Of these the fish was the last and most powerful, and it cleared the open seas of all competitors.

Only from some such cause as this can we understand the sudden appearance of the Cambrian Orthoceratites, with their bulky and clumsy shells, which certainly would never have been developed except through pressure of sheer necessity. This armor must have greatly diminished the motor powers of the cephalopod; it was solely protective in character, and it is impossible to impute it to any cause save that of defense from a powerful predacious foe. All the early lords of the ocean had successively to clothe themselves in strong armor, or to vanish from existence as more powerful forms appeared.

There are strong indications, therefore, that in addition to the armored forms preserved in the rocks, there was abundance of naked forms of life, mainly swimmers, and pursuing a predatory mode of life. If we pass backward through the succession of fossil forms, it is to find the armored types decreasing in numbers and variety. We seem to gradually approach a period in which the naked swimming forms were greatly in excess. This may have been preceded by a period in which there were no armored forms. In such a case, though life may have been as abundant as now, it could not have been fossilized. Such may possibly have been the pre-Cambrian life condition.

There could have been no era of life, indeed, in which predatory forms did not exist. But there may have been a long period during which animals were incapable of secreting armor. The

organic functions are certainly not all of primitive origin. Many of them may have been the product of ages of slow development. Such may have been the case with the development of glands suitable for the secretion of chitin, carbonate of lime, and the other protective substances. We know that it was at a late date in the history of life when animals first began to secrete an internal hard skeleton. The need of protection undoubtedly caused a more rapid evolution of the power to secrete an external hard covering, and yet life may have long prevailed before this adaptation was gained. The mantle of the bivalve mollusks, for instance, with its glands for the secretion of a limy shell, cannot have been a primitive feature of molluscan life. So the chitin-forming glands of the crustaceans may have been a late product of evolution. It is possible that, in the early days of life, all the mineral ingredients of food were directly excreted. It is equally possible that the power of transforming food elements into hard substances did not exist. The development of dermal glands, necessary to the secretion of external skeletons, teeth, etc., must have occupied a considerable time, and its completion may have taken place but shortly before the opening of the Cambrian period.

If such was the case, the preceding life must have been of a low order, and of small dimensions. Animals might have grown to considerable size with cartilaginous skeletons, but scarcely without teeth or other hard weapons of offense, of which no trace remains. It may be that the earlier forms of life were in great part swimming animals, that they waged constant war upon each other, and that in time, through the action of natural selection, the power of secreting defensive armor was evolved. As this armor grew denser and heavier the swimming powers became abridged, and the armored animals were successively carried to the bottom, and forced into slow-moving or stationary habits of life.

In corroboration of this idea is the fact that the power of secreting an internal skeleton appeared only at a much later date. It has never been developed in the Invertebrates, except in late cephalopods, and in all these animals the external armor has necessarily been utilized for muscular attachment. The superiority of the vertebrates is largely due to the fact that their muscular attachment has always been internal, a method which gives much greater flexibility and power of movement. Yet for a long period after the appearance of vertebrate life the basis of muscular attachment was merely a rod of cartilage. Even the great Devonian fishes, with their dense epidermal plates, were destitute of internal bone, except that in a few cases they possessed ossified vertebral arches. The next evidence of power to secrete internal bone is found in certain Carboniferous Ganoids, which possessed a mere ring of bone in the external portion of their vertebræ. It cannot reasonably be argued that bony skeletons

would have been of no use to these ancient swimmers. The possession of bony skeletons by all the Teleostei shows that this adaptation is a valuable one. Modern Sharks and Ganoids, while often cartilaginous, frequently possess completely ossified vertebræ. Thus we have reason to believe that the absence of internal bone in the most ancient fishes came from the fact that the conditions for the secretion of such bone had not yet been developed.

This leads to one further conclusion. Though a cartilaginous basis of muscular attachment might suffice for large swimming animals, it would not answer for large forms of terrestrial life. In these a greater rigidity was necessary. Therefore land vertebrates of large size could not appear until after the power of forming a bony skeleton had been attained. And it is significant that shortly after the appearance of bone in fish skeletons the Batrachians make their appearance in the rocks. We know that the land had been adapted for animal life for long ages before, and peopled by insects and scorpions, and possibly by forms of life of which we have no comprehension. It is very probable that fishes had long used the land as a temporary place of residence and feeding-ground. This we may safely infer from the existence of fossil Dipnoi, with their powers of breathing air or water at will. Yet it was impossible that large land vertebrates could appear until the bone-making power was fully developed. *Archægosaurus* one of the earliest air-breathers, possessed but a ring of bone in its vertebræ, like the Carboniferous Ganoids. But in all the remaining Carboniferous Batrachians a fully ossified skeleton appears, and this has been ever since an absolute requisite of all land vertebral life, and of all ocean vertebrates except a few survivals of the antique types.

Thus we reach the general conclusions that fossilization of animal forms was not possible until, after a long period of evolution, the power of secreting hard external coverings was gained; and that the existence of large land vertebrates was not possible until, after a still longer period of evolution, the power of secreting internal bony skeletons was developed. If these conclusions be well founded, many of the conditions of early life must remain forever unknown to us, and we cannot hope to recover more than a fragment of the antique fauna.

APRIL 14.

The President, Dr. LEIDY, in the chair.

Thirty-one persons present.

A paper entitled "Notes on Mesozoic Cockroaches," by Samuel H. Scudder, was presented for publication.